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Do oarsmen have asymmetries in the strength of their back and leg muscles?

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The aim of this study was to establish whether asymmetry of the strength of the leg and trunk musculature is more prominent in rowers than in controls. Nineteen oarsmen and 20 male controls matched for age, height and body mass performed a series of isokinetic and isometric strength tests on an isokinetic dynamometer. These strength tests focused on the trunk and leg muscles. Comparisons of strength were made between and within groups for right and left symmetry patterns, hamstring : quadriceps ratios, and trunk flexor and extensor ratios. The results revealed no left and right asymmetries in either the knee extensor or flexor strength parameters (including both isometric and isokinetic measures). Knee extensor strength was significantly greater in the rowing population, but knee flexor strength was similar between the two groups. No difference was seen between the groups for the hamstring : quadriceps strength ratio. In the rowing population, stroke side had no influence on leg strength. No differences were observed in the isometric strength of the trunk flexors and extensors between groups, although EMG activity was significantly higher in the rowing population. Patterns of asymmetry of muscle activity were observed between the left and right erector spinae muscles during extension, which was significantly related to rowing side ($P < 0.01$). These observations could be related to the high incidence of low back pain in oarsmen.

Keywords: isokinetics, quadriceps : hamstring ratio, rowing, strength, symmetry, trunk strength.

Introduction

Rowing has a low rate of injuries compared to other sports (Hickey *et al.*, 1997). Stallard (1980) reported an increase in the incidence of spinal problems, a trend that has continued (Roy *et al.*, 1990; Green, 1998). It has been speculated that injuries arise as a result of the intensive training regime of rowers (Jones *et al.*, 1994; Hickey *et al.*, 1997); others blame the rowing action or technique (Stallard, 1980; Hagerman, 1984; Hosea *et al.*, 1989), a factor that has been compounded by changes in rowing technology (Stallard, 1980; Christiansen and Kanstrup, 1997). However, no scientific evidence supports claims of increased rates of injury.

Sweep rowing involves the oarsmen loading the back in a rotated and flexed position. This asymmetric activity may lead to the development of muscle asymmetry and injury (Hides *et al.*, 1994; Hodges and Richardson, 1996). It has previously been noted that imbalance leads to a high rate of both injury and re-injury (Marshall and Tischler, 1978; Campbell and Wayne, 1979; Knapik *et al.*, 1990). Thus, prophylatic selective strengthening programmes are postulated to correct weakness and imbalance and thereby reduce the occurrence of injuries (Cahill and Griffith, 1978; Slagle, 1979; Knight, 1980; Heiser *et al.*, 1984). Few studies have investigated the relationship between imbalance in muscle strength and the occurrence of injuries. Kramer *et al.* (1991) identified asymmetry in the isokinetic strength of the quadriceps muscle group in oarsmen. Koutedakis *et al.* (1997) noted a low hamstring to quadriceps strength ratio, suggesting weakness of the hamstring muscle groups in rowers with low back pain. They suggested that this abnormal hamstring : quadriceps ratio might

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interfere with the lumbo-pelvic rhythm, leading to increased stress on the spine.

It remains unclear, however, if uninjured rowers present with asymmetries in the leg and back. The aim of this study was to determine whether asymmetry of the strength of the leg (including left and right hamstring : quadriceps ratios) and trunk musculature (flexor : extensor ratio and symmetry of muscle activity) is more prominent in rowers than in controls.

Methods

Participants

Thirty-nine males were recruited, 19 of whom were rowers and 20 of whom were non-rowing controls. The two groups were matched for age, height and body mass where possible. The oarsmen were aged 19–26 years (mean ± *s*: 21.2 ± 2.1 years); 10 rowed stroke side and 9 rowed bow side. They had rowed for 6.2 ± 3.1 years; all had rowed at national standard and 17 had been junior internationals. The 20 controls, who were aged 20–24 years (21.0 ± 4.6 years), were recruited from the non-rowing student population. None of the participants had any back or leg pain at the time of testing. Written informed consent was obtained from all participants before participation in the study and local ethical committee approval was obtained.

Strength testing equipment

Muscle strength was determined from measurements of force using an isokinetic dynamometer (Kin-Com, Chettecz Corp., Chattanooga, TN). This system has previously been shown to be accurate and repeatable with a coefficient of variation of less than 10% (Gallagher, 1997; Holder-Powell and Rutherford, 1999).

Assessment of hamstring and quadriceps muscle strength. Knee flexion and extension were assessed in the sitting position. The strain gauge, attached to the lever arm, was firmly strapped around the leg, just above the ankle. The height of the chair was adjusted for the centre of rotation of the knee joint. Forces to start the movement were set at 100 N for extension and 70 N for flexion and gravitational adjustments were made to allow for the weight of the lower limb. After familiarization with the equipment, two sets of isokinetic concentric contractions of the extensor and flexor muscle groups were performed, initially at 3.5 $rad \cdot s^{-1}$ and then, after 60 s rest, at 1.75 $rad \cdot s^{-1}$. Next, the force produced by the extensor muscle group when performing an eccentric contraction at 1.75 $rad \cdot s^{-1}$ was determined. After sufficient recovery, three sets of isometric contractions of both the extensor and flexor muscles were performed at 90° knee flexion, with each contraction being sustained for a minimum of 3 s. All measurements were performed on both the right and left leg.

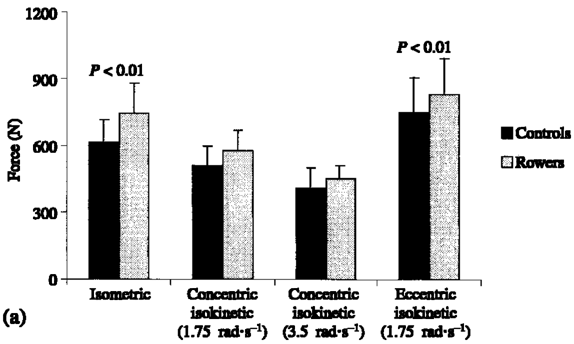
Assessment of back muscle strength. Attachments were engineered for the Kin-Com system to enable the measurement of back flexor and extensor isometric strength. For extension, the strain gauge was placed such that its centre rested below the inferior aspect of the participant's scapulae. The participants were asked to extend, pushing against the moment arm as hard as they could. For flexion, the system was repositioned such that the strain gauge was centred over the inferior aspect of the sternum. In this position, the participants were asked to cross their arms and push forward on the moment arm to which the strain gauge was attached as hard as they could. During all test procedures, a back support was provided and the legs and pelvis were restrained with straps to isolate the movement to the lumbar spine. Both the flexion and extension measurements were repeated three times and each time the participant was asked to maintain the contraction for 3 s.

EMG recordings

During isometric testing of trunk extension strength, the activity from the left and right erector spinae muscle groups was recorded using electromyography (EMG) as a measure of symmetry. EMG activity was recorded by channelling the Kin-Com force transducer signal to a data acquisition system (Cambridge Electronic Design Ltd, Cambridge, UK). This permitted simultaneous recording of force and EMG activity. The EMG was recorded differentially using 22 mm self-adhesive surface electrodes (Arbo, Henley Medical Systems, Welwyn Garden City, UK) positioned over the left and right erector spinae muscles at the level of the 2nd and 3rd lumbar spinous processes. The EMG signals were analysed using Spike 2 (version 3) software (Cambridge Electronic Design Ltd, Cambridge, UK). Mean EMG activity was determined during a 0.5 s period of peak isometric force, and mean resting EMG was subtracted from mean EMG at peak force.

Statistical analysis

Analysis of the data was performed using the statistical package Stata (Stata Corporation, Texas, USA). A two-way analysis of variance (ANOVA) with repeated measures was used to compare differences between and within the two groups for the left and right sides. An interaction term was also used to determine if



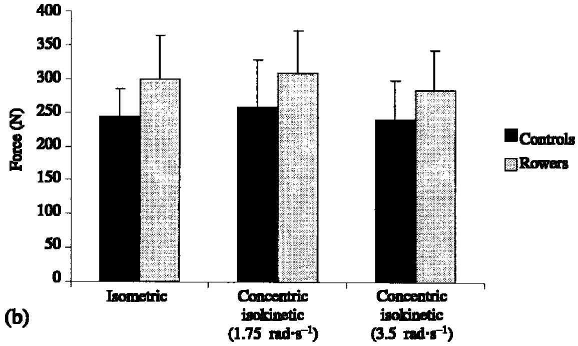


Fig. 1. (a) Group mean quadriceps strength for controls (n = 20) and rowers (n = 19). (b) Mean group strength for the hamstring muscle group (mean values for both legs; error bars represent the standard deviation).

asymmetries were more marked in one or other of the two groups. The statistical threshold was set at $P < 0.05$. Back strength was compared between the two groups using Student's t-test.

Results

Table 1 shows that the two groups were similar in age; however, the oarsmen tended to be taller and heavier than the controls. Ninety per cent of the rowers and 80% of the controls were right-handed. Ten of the rowers rowed stroke side (i.e. with the blade on the right-hand side of the body), while the remainder rowed bow side (i.e. with the blade on the left-hand side of the body). Most of the rowers had experienced low back pain in the past but were not experiencing such pain at the time of testing; none had required intervention for their back problem other than physiotherapy.

Knee extensor strength

For the two groups, both isokinetic and isometric parameters of strength of the left and right knee extensor muscles were compared. This revealed that strength was similar in the left and right legs of both the oarsmen and the controls. The ANOVA revealed that the oarsmen were significantly stronger in both isometric and eccentric (3.2 rad $\cdot$ s^{-1}) knee extensor strength (Fig. 1a).

Knee flexor strength

As with the knee extensor data, no statistical differences were noted between the right and left legs for either group. The ANOVA revealed no significant differences in strength for all parameters tested between the two groups (Fig. 1b).

Hamstring : quadriceps ratio

The balance in strength between the hamstring and quadriceps (knee flexor and extensor) muscle groups in both legs was also determined. This revealed little or no difference between each leg and no difference between the two groups for both isometric and isokinetic strength tests (Table 2).

Influence of rowing side

A further sub-analysis was performed on the oarsmen to establish the impact of rowing position on leg strength. In stroke-side rowers, the left leg was considered to be dominant; in bow-side rowers, the right leg was considered to be dominant. Inclusion of the rowing position within the ANOVA revealed no significant differences in the strength of either the quadriceps or hamstrings.

Back strength and symmetry of contraction

No differences in strength were observed between the two groups (Fig. 2). However, analysis of the EMG

Table 1. Physical characteristics of the oarsmen and control group (mean ± s, with range in parentheses)

	Oarsmen	Controls
Mean age (years)	21.7 ± 2.7 (19–26)	21.0 ± 4.6 (20–24)
Height (m)	1.88 ± 0.04 (1.80–1.94)	1.84 ± 0.07 (1.73–2.03)
Body mass (kg)	85.1 ± 5.6 (74.0–97.5)	83.3 ± 12.3 (68.0–107)

Table 2. Hamstring : quadriceps ratio of the oarsmen and control group (mean ± *s*)

	Oarsmen (%)	Controls (%)
Concentric isokinetic, 3.5 rad · s^{-1}	63.5 ± 10.1	59.7 ± 13.6
Concentric isokinetic, 1.75 rad · s^{-1}	54.7 ± 9.1	51.1 ± 12.6
Isometric	41.8 ± 12.8	41.7 ± 9.9

results showed significantly stronger EMG signals in the oarsmen in extension and flexion ($P < 0.001$), with a trend towards left and right asymmetry in the oarsmen ($P = 0.07$) in extension (Fig. 3). The ANOVA revealed that this asymmetry in oarsmen was related to rowing side ($P < 0.01$).

Discussion

Due to the highly competitive nature of rowing and the associated training, it is reasonable to expect asymmetry and imbalances in the leading muscle groups. A strength discrepancy of 10–15% or more between the two sides is considered to represent a significant asymmetry (Elliot, 1978; Gleim *et al.*, 1978; Kannus, 1994). It has been postulated that the weaker or more imbalanced an extremity muscle group is, the more prone it is to injury (Slagle, 1979; Knight, 1980). However, others have questioned whether there is a link between muscle imbalance and injury (Grace *et al.*, 1984). Similarly, the presence of asymmetry has been linked to injury.

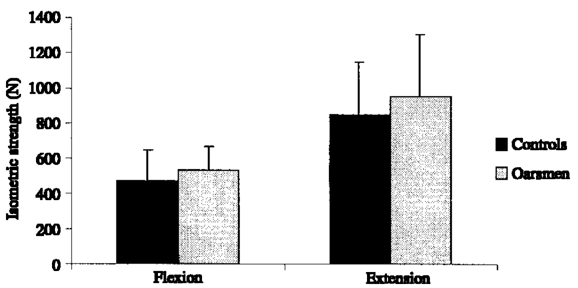


Fig. 2. Isometric strength of the trunk flexors and extensors for controls ($n = 20$) and rowers ($n = 19$) (error bars represent the standard deviation).

The aim of this study was to determine the impact of the sweep rowing action on the forces generated by the quadriceps, hamstring and trunk muscles. The results showed that, in both groups, irrespective of hand dominance or rowing side, there were no significant differences between the right and left legs for isokinetic and isometric strength of the quadriceps and hamstring muscle groups. This suggests that the action of rowing on the legs does not lead to asymmetry.

Left and right asymmetry was observed in EMG activity of the lumbar erector spinae muscle groups during the trunk extension tests among the oarsmen. This was significantly related to rowing position. Observation of the rowing stroke suggests that the rotated position required in rowing is achieved through the trunk. Surprisingly, the rowers' trunk muscles were only slightly stronger than those of the controls. This is of interest when compared to the large differences observed in the knee extensor muscles. From these observed differences in the leg muscles, a larger margin of difference in trunk strength had been anticipated, especially because of the nature of the sport. This may be related to trunk injuries (Lee *et al.*, 1999) and requires further investigation.

As well as bilateral asymmetry, imbalances can occur between the agonist and antagonist muscles.

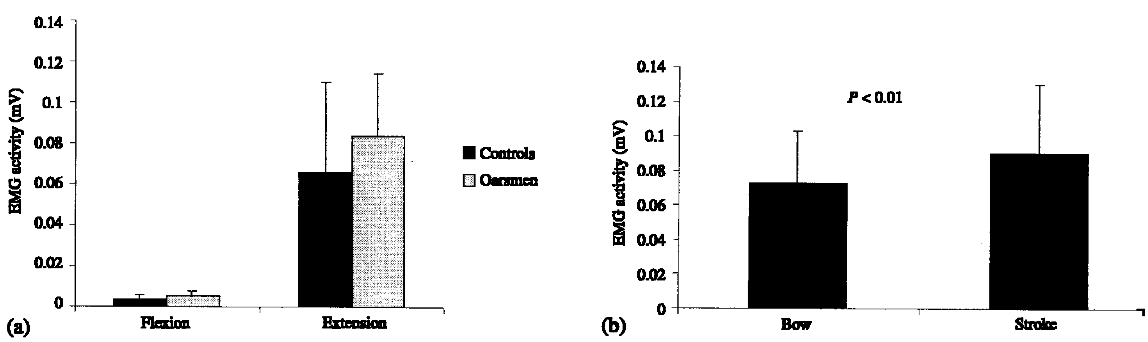


Fig. 3. EMG activity (mV) in (a) controls ($n = 20$) and oarsmen ($n = 19$) with left and right sides averaged (error bars represent the standard deviation); (b) the oarsmen only.

Although large inter-individual variation exists, the optimal hamstrings : quadriceps ratio in both trained and untrained individuals appears to be between 55 and 80%, depending on test speed (Imwold *et al.*, 1983; Colliander and Tesch, 1989; Wyatt and Edwards, 1989; Kannus and Järvinen, 1990; Knapik *et al.*, 1990; Read and Bellamy, 1990). The hamstring : quadriceps ratios during the dynamic tests were in line with those previously published.

Using dynamic tests, Koutedakis *et al.* (1997) assessed the hamstrings : quadriceps ratio in competitive oarsmen and women and noted ratios of 51% and 50% at 1.05 $rad \cdot s^{-1}$ in males and females respectively. Koutedakis *et al.* attributed these low ratios to the under-development of the hamstring muscles during rowing. They also noted that the low hamstring : quadriceps ratios were associated with increasing severity of back injuries. They attributed this to the role of the hamstrings in controlling the pelvis, postulating that powerful quadriceps muscles combined with weak hamstrings could alter the rotation of the pelvis during the stroke, altering the lumbo-pelvic rhythm and forcing the athlete to gain reach and power from the lumbar spine. The instigation of a hamstring strengthening regime in female rowers was found to reduce the incidence of injury (Koutedakis *et al.*, 1997). It is difficult to compare the results of Koutedakis *et al.* with those of the present study, since different isokinetic test speeds were used. Also, their study concentrated on a group of female rowers while the present study focused on male athletes. These differences may be related to the training regimes of the two groups of rowers, different standards of rowing and a slight difference in mean age.

In conclusion, the rowers in the present study exhibited greater strength in their thigh muscles than a group of controls. Surprisingly, the back muscles were not stronger in the oarsmen. Further investigations are required to determine if the incidence of low back pain is related to this apparent weakness in the back muscles. There did not appear to be any asymmetries between sides in either group for the muscles investigated. More detailed investigation is required of the components of each muscle group, such as measures of cross-sectional area and density obtained from magnetic resonance imaging and computed tomography.

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